CLR's Role in the Security Tapestry

Charlie Kaufman
Microsoft Corporation

Agenda

- **Why this stuff is important!**
- Sandboxing in its many forms
- How the CLR works
- The hard problems that remain

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Is this asking so much?

- I'd like to be able to trade stocks over the web with security comparable to calling my broker on an 800 number
- (Note: this is not a very high bar… there is a lot that can go wrong over the phone)

Things I would expect of a telephone

- Only someone really motivated can eavesdrop
- I know I'm talking to the party whose number I dialed
- The party I call may learn my phone number, but won't learn who else I've called or what I said to them
- I can talk to anyone I want without fear of damaging my phone

Why is this hard?

- Active Content
- If you run a program I wrote, it can do things with your rights behind your back
  - Read your private files and send them to me
  - Delete or mangle files you have rights to access
  - Send email composed by me but sent (provably!) by you
  - Authorize me to do things later (if you can add me to ACLs)

Why would you run a program I wrote?

- I might trick you into it
  - Look at this great game!
- You might not think of it as running a program
  - Display a PostScript file
  - Display a Microsoft Office document
  - Visit my web site
  - Open my email message

Why should any of these involve running a program?

- Bandwidth and storage efficiencies
  - A program can more concisely express something than a static description
- Flashy graphics and interactive animation
- Extensibility

Is there any safe way to run my program?

- Since the '50s, computers were designed to safely run programs from hostile users
  - Memory bounds checking built into hardware
  - Operating systems enforced access control lists
  - But… assumed users responsible for the software they ran
  - Users need to easily (and mostly transparently) run programs with a subset of their rights

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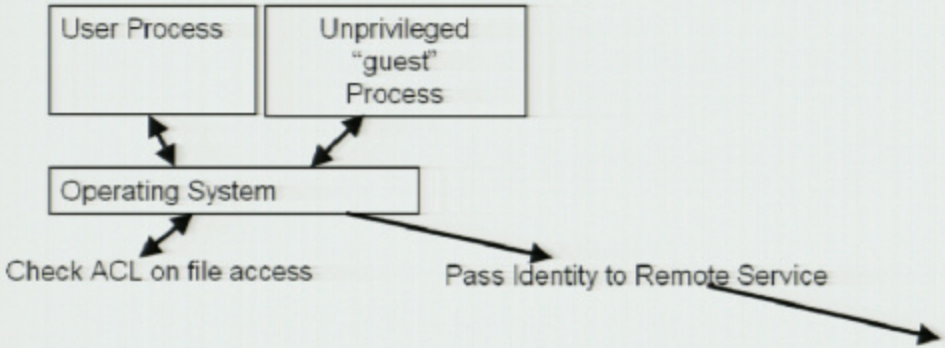
Sandboxing

- Running a program with limited access to resources
  - Traditionally, at the level of the process
  - Alternately, you can emulate PC hardware and run an entire virtual machine
  - Computers are cheap enough that you can even use separate physical machines
  - With strong typing, secure isolation can be achieved within a process

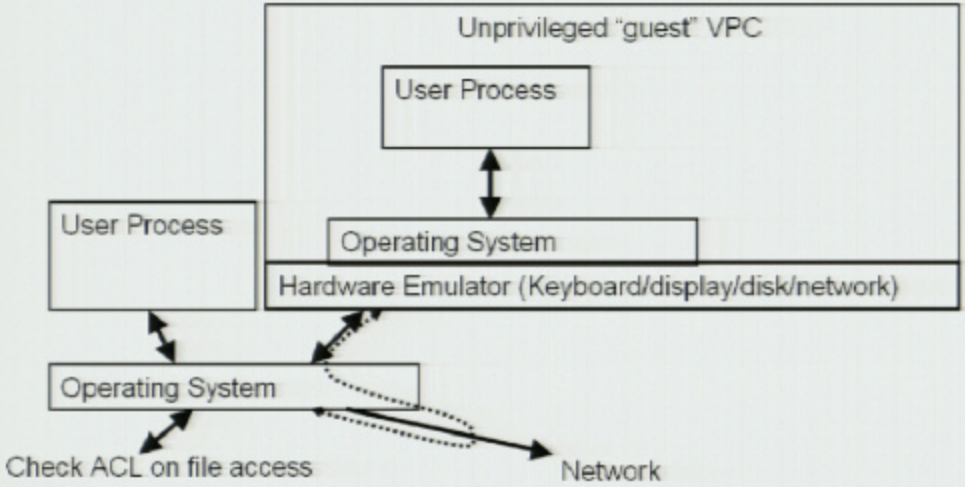
Sandboxing with Processes



Sandboxing with Processes

- A process should be able to launch a process with lesser rights
  - I want to run your game, or display your PostScript, but I don't want it to be able to open my files
- A process should be able to communicate with a process with greater rights
  - Your program should be able to access databases through a DBMS, where the DBMS knows who you are and enforces ACLs

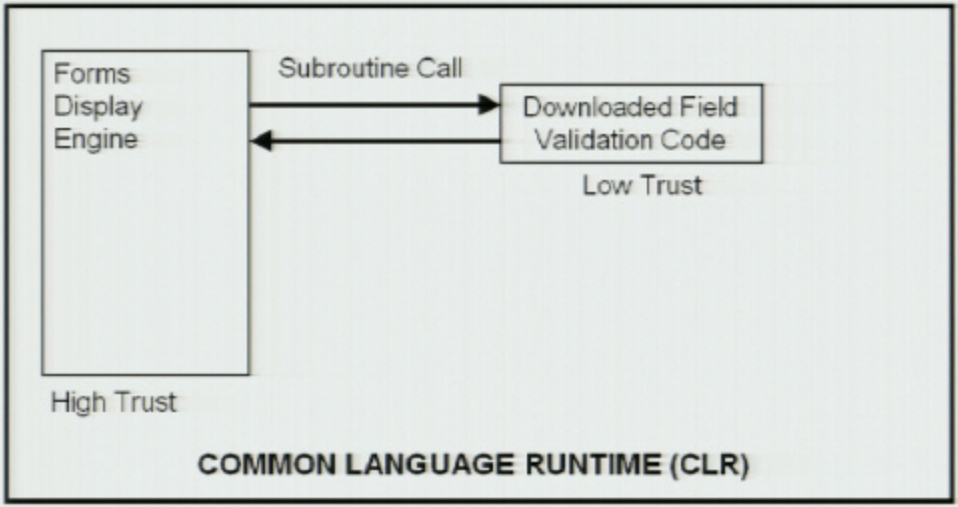
Sandboxing with VPC



Sandboxing with VPC

- A virtual PC should have no access to host system resources except through the emulated hardware
- File sharing and other interaction should use network protocols (as though there were separate physical machines)
- Keyboard/Display/Clipboard sharing represent special challenges

Sandboxing within a Process



How does strong typing help?

- In a traditional programming language, testing of data types and array bounds are an aid to help detect bugs
- With strong typing, even a malicious program cannot access process memory to which it is not given access
- Theoretically, hardware memory bounds protection becomes unnecessary (or at least redundant)

Which form of sandboxing is best?

- It depends on what you're trying to do
  - Security
  - Performance
  - Functional Richness
  - Compatibility
  - User Experience
- We plan to implement all of them for different scenarios

How secure can you make a sandbox?

- Bugs in the enforcement code can allow sandboxed code to “escape”
- Bugs in services offered can allow sandboxed code to elevate its privilege
- Bounds checking in hardware improve performance, but for security you have to have a correct TCB:
  - OS for process isolation
  - JIT, CAS, and privileged services for CLR
  - Hypervisor for VPC

How performant can you make a sandbox?

- Cost of creating and deleting sandboxes
  - How much state do they carry
- Overhead of emulation of services outside the sandbox and of context switches
- CLR better than Process better than VPC

How much functionality can you safely expose in the sandbox?

- In theory, they all could safely expose the same functionality
- In practice:
  - Because CLR limits language expressiveness, it is an unlikely host for “full function” applications
  - Processes and VPC are rich enough for all but specialized hardware interfaces

How backwards compatible can you make a sandbox

- VPC can (in theory) perfectly emulate native machine except for performance of access to specialized hardware
  - In practice, limited hardware emulation
- Process isolation can run unmodified applications that don't elevate privilege
- CLR does not attempt to sandbox applications that were not designed to fit in the sandbox

How transparent can you make sandboxes to the user?

- Transparency is not always a good thing
- The system has to figure out what the user wants
- With the CLR, application code can implement the user interaction experience (e.g. prompting for a file to open)
- With process isolation, and even more so with VPC, shared GUI and system clipboard are difficult to implement

What do we use them for?

- VPC
  - Server Consolidation
  - Compatibility testing with diverse configurations
  - Future direction: Red/Green client protection
- Process Isolation
  - Isolation of services on a shared server
  - Terminal Server
  - Unprivileged user vs. Administrator
  - Future direction: Processes with subset of user's permissions (e.g. LUA / PA)

What do we use them for?

- Code Access Security / CLR
  - Sandboxed applications launched from web sites (comparable to Java and JScript)
  - ASP.NET sandboxed servlets
  - Future direction: richer application environment for web applications
    - Goal is to support a safe rich high performance user interaction with server based applications (e.g. games, teleconferencing, brokerage sites, auction sites)

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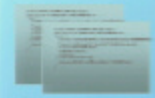
- **How the CLR works**
- The hard problems that remain

Basics of CLR

- Compilers generate 'IL' instead of native machine code
- IL is a strongly typed assembly language
- IL is 'verified' and compiled into native machine code by a Just In Time (JIT) compiler
- JIT assures type safety enforced, but produces fast machine code
- IL step makes verification possible in a language independent way and provides platform independence

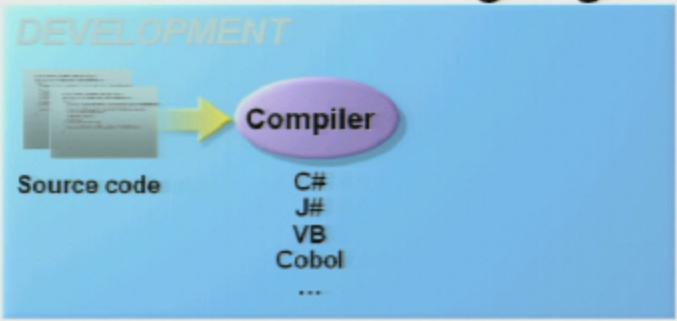
Common Language Runtime

DEVELOPMENT



Source code

Common Language Runtime



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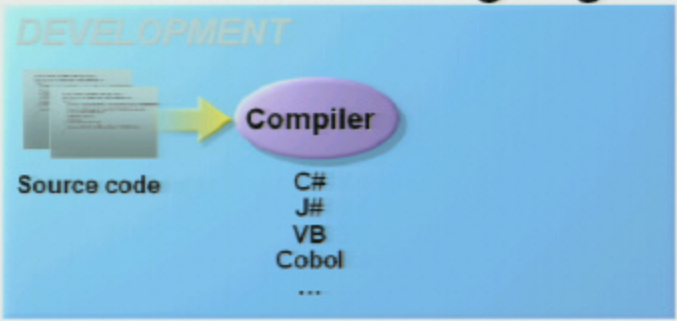

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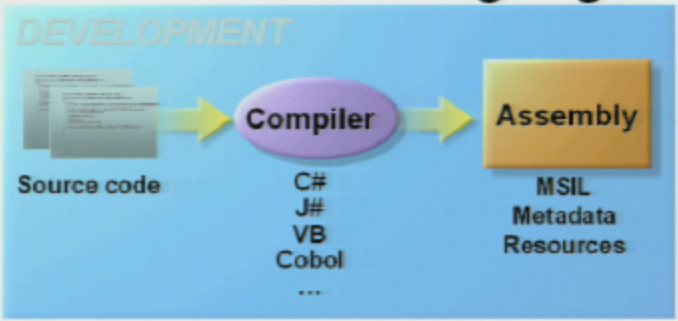

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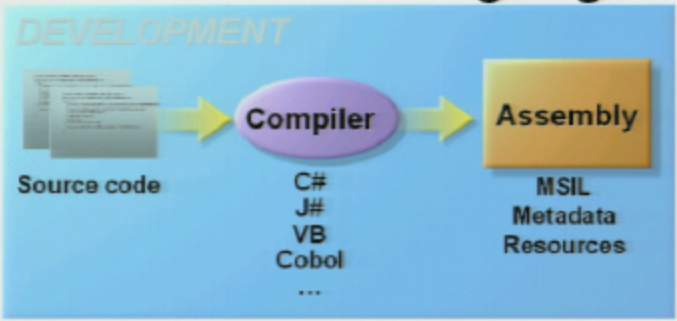

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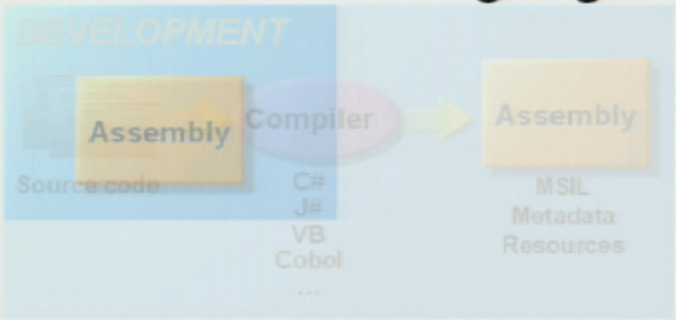

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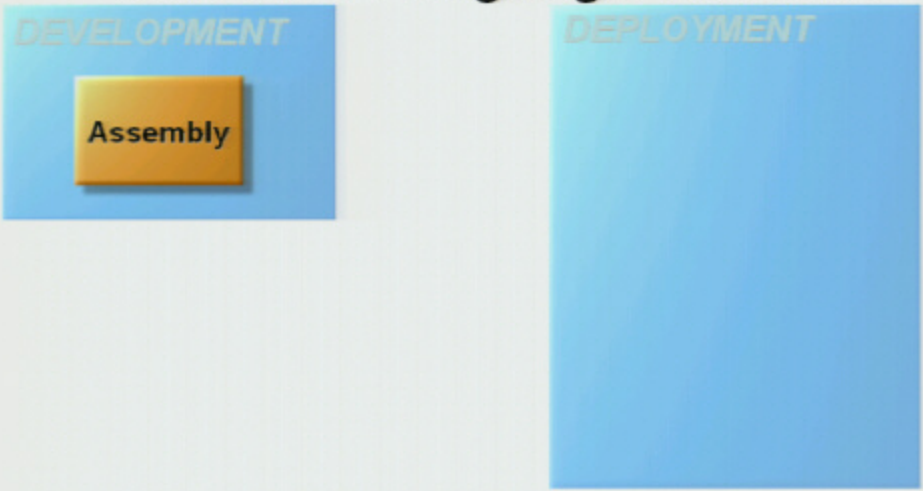

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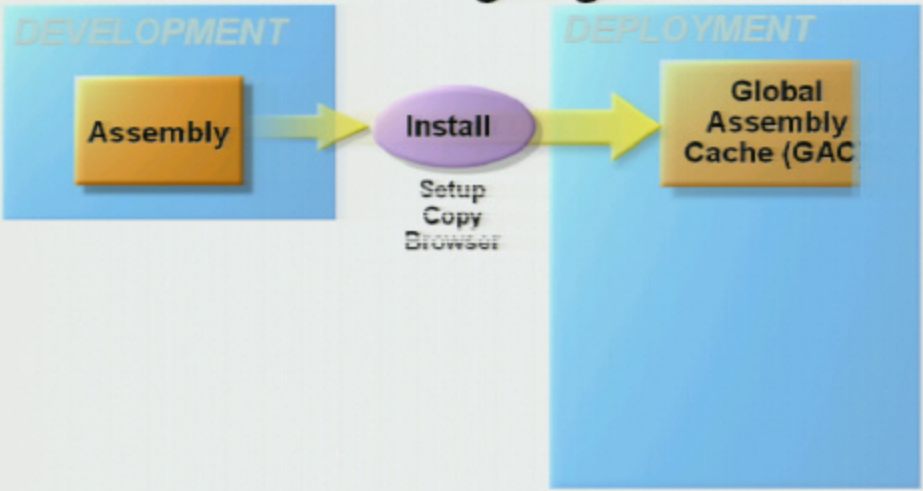

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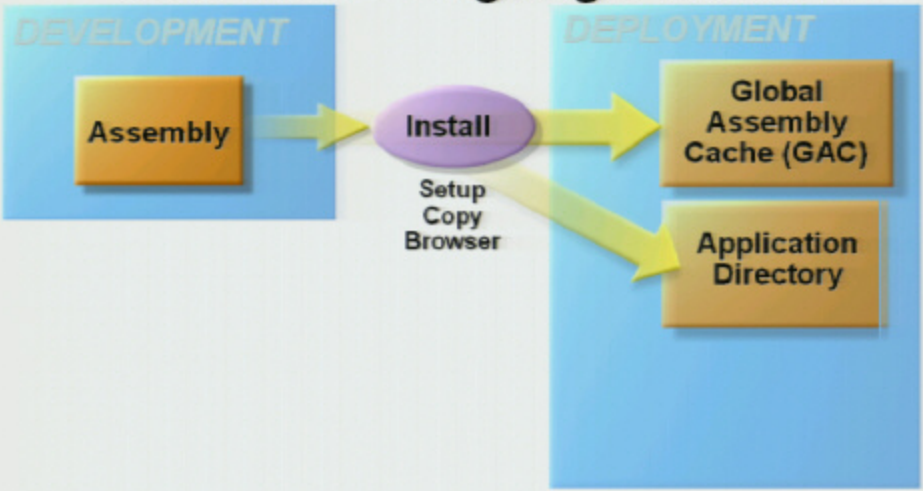

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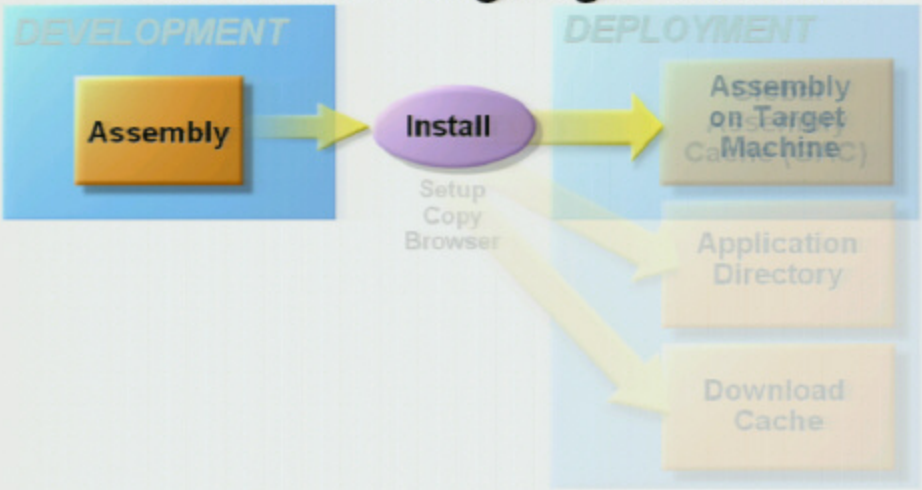

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Problem 1: How to decide what code to trust?

- Based on digital signatures from publishers
- Based on the web site they came from
- Based on configuration settings (the architect's cop out – how is the administrator to know)
- The code that loads the code might have an opinion
- Based on user input

CLR's Approach

- Trust Policy Engine
- Input is assembly 'evidence'
- Enterprise, Machine, User, and Application policy levels are evaluated and intersected
- Click once install lets user adjust policy

Problem 2: How to make it easy to write ‘safe’ library code

- The problem:
  - Every subroutine library (assembly / .dll) has an independently determined level of trust based on its evidence
  - By default, code runs with the intersection of the rights of itself and everyone above it on the call stack
  - Code can ASSERT up to its own rights
  - Code can PermitOnly to any smaller set of rights

Problem 2: How to make it easy to write 'safe' library code

- Code must ASSERT to provide mediated access to system resources (e.g. check a 'display this string' request to make sure it fits in the destination window)
- Code must be paranoid in checking parameters to avoid luring attacks
  - Akin to the kernel code that checks requests from user processes
  - Type safety helps, but does not solve the problem

Problem 2: How to make it easy to write ‘safe’ library code

- Challenge: create coding practices that isolate security critical code so that not everything has to be inspected so carefully
- Analogy to user mode .dlls separate from kernel mode .dlls

Problem 3: What permissions are 'safe' to grant?

- In the OS, permissions mostly centered on what files can be accessed
  - Users belong to Groups
  - Users and Groups are listed on ACLs
- A downloaded game might need:
  - 'Isolated storage' for saving its own state
  - Access to system files like fonts and screen geometry information
  - Access to the network to interact with its peers in a multi-player environment

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  - Access to specific web sites
  - Access to subtrees of the file system
  - Access to specific windows on the user’s screen
  - Mediated access to files: put up a dialog box and let the user select a file, but don’t open one directly

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Where are we headed with CLR?

- A Secure Execution Environment (SEE) modeled on what script on a web page downloaded from the Internet can do
  - Mediated access to file system and printer
  - Ability to connect back to its source server
  - More privileges based on configuring trusted publishers and user prompting

Where are we headed with CLR?

- Principle of Least Privilege: run applications only with rights they declare they need in their manifests
- Sand Dunes: If a sandbox constrains a program to safe things, a sand dune makes it hard to wander too far off by accident

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  - Access to my tax information
- How do I let a program access some sensitive things without completely opening up my system to it?

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Problem 4: The Russian Doll model of Sandboxes

- I want to use Hotmail, but don't trust it
- Hotmail wants to display email messages, but it doesn't trust them
- Someone may want to send me email with an embedded ad, but he doesn't trust the ad
- The Hotmail service may be hosted on a commercial web service provider who doesn't trust the service code.

How many different trust levels?

- Isolate individual lines of code?
- Isolate assemblies?
- Isolate App Domains?
- Isolate processes?

Problem 5: Making CLR, OS, and Web Security more similar

- All need to recognize user identity and program identity is inputs to access decisions
- Differences based on their evolution, not real needs
- People have a hard enough time learning one system; they aren't going to learn three.

Questions?

Agenda – Day One

- *8:30AM* — *Continental Breakfast and Open Discussion/Updates*
- *9:30AM* — *BREAK*
- *9:45AM* — *Longhorn Security Overview*
- *11:00* — *BREAK*
- *11:15* — *Internet Explorer Security Overview*
- *12:30PM* — *BREAK / LUNCH*
- *12:45PM* — *WORKING LUNCH - Common Language Runtime - Security Architecture Overview*
- *2:00PM* — *BREAK*
- *2:15PM* — *Microsoft Privacy Standard Update – SDL Integration*
- *3:45PM* — *ADJOURN FOR DAY – BUS TO MSCC FOR TECHFEST*
- *5:45PM* — *BUS LEAVES MSR FOR HYATT BELLEVUE*
- *7:30PM* — *Dinner – Daniel's Broiler – Bellevue*